Wilson Bull., 90(3), 1978, pp. 423–437

ANALYSIS OF ROOSTING COUNTS AS AN INDEX TO WOOD DUCK POPULATION SIZE

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Autumn roosting habits of Wood Ducks (*Aix sponsa*) have been studied throughout much of their range (Hester and Quay 1961, Hester 1965, Hartowicz 1965, Hein and Haugen 1966, Tabberer et al. 1971), but the use of roosting flight counts as a population index is controversial. An Iowa study (Hein 1965, Hein and Haugen 1966), concluded that fall roosting flight counts could furnish an index which would detect changes of 15% in annual abundance of Wood Ducks. In contrast, Tabberer et al. (1971) studied 44 roosts in Louisiana and concluded that flight counts were invalid due to variations in quality and stability of individual roosts. Smith (1958), in his study of roosts in Louisiana, felt that the technique was invalid because of yearly fluctuations in the amount of surface water in roosts.

If a roost count is to be a valid index technique, the following assumptions must be met (also see Hein and Haugen 1966): 1. Each roost is a geographically discrete area, which contains an identifiable Wood Duck population separate from other roosts. 2. The number of Wood Ducks using a roost reflects the general abundance of the species in the area, and the Wood Ducks congregate at the roost solely as a result of their social needs, not due to a presence, or absence, of food or water elsewhere. 3. All, or at least a consistent proportion, of the Wood Ducks flying to a roost are susceptible to being counted during any given counting event. 4. All, or at least a consistent proportion, of the Wood Ducks in an area fly to identifiable communal roosts in the evening. 5. Little unilateral inter-roost movement occurs.

We gathered and analyzed movement data on individual ducks, as well as on whole flocks to determine if these assumptions were valid for roosting Wood Ducks in southern Illinois.

STUDY AREAS AND METHODS

Three study areas were used (Fig. 1). The 2960 ha Union County Wildlife Refuge is located on the Mississippi River floodplain approximately 13 km west of the town of Anna. It contains 3 open-water lakes, plus several areas of standing timber which are artificially flooded in the fall. There are also scattered swampy areas in which buttonbush (*Cephalanthus occidentalis*) is the principal species. Uplands are composed of grain fields interspersed with oak (*Quercus* spp.)—hickory (*Carya* spp.) forest.

The 770 ha LaRue-Pine Hills Ecological Area is located approximately 14 km north of the Union County Refuge. The area is a swamp dominated by buttonbush, water willow (*Decodon verticillatus*) and American lotus (*Nelumbo lutea*). It has previously been described by the U.S. Forest Service (1970).

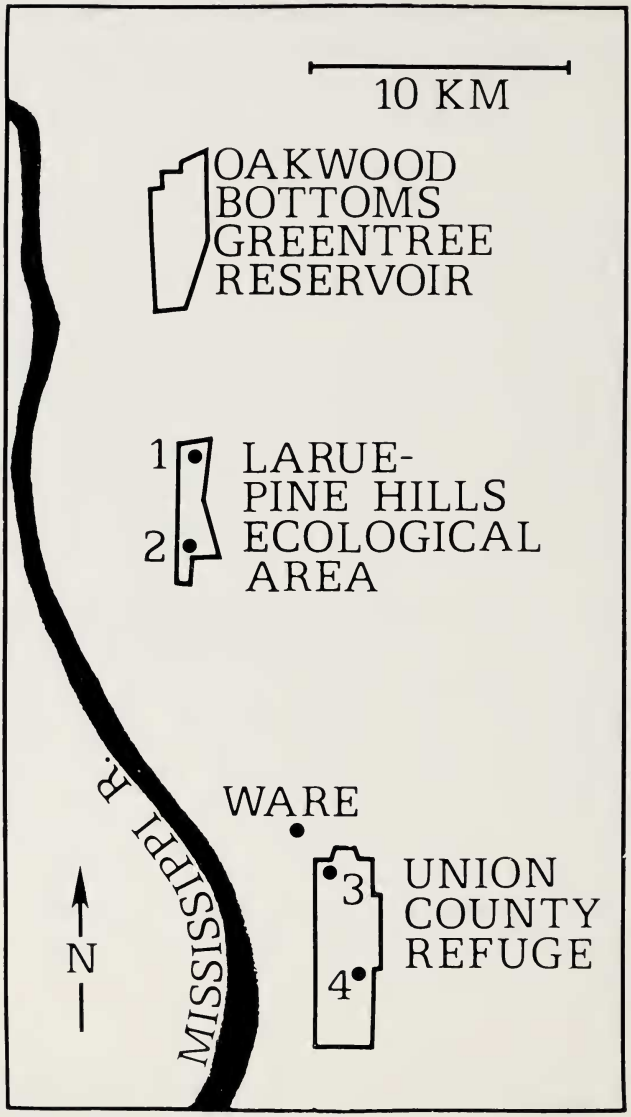

FIG. 1. Location of the 3 southern Illinois study areas and the 4 Wood Duck roosts. (1) North Pine Hills Roost; (2) South Pine Hills Roost; (3) Grassy Lake Roost; and (4) Triangle Roost.

The 1215 ha Oakwood Bottoms Greentree Reservoir is located in Jackson County, approximately 24 km north of the Union County Refuge. The dominant plants are pin oaks (*Quercus palustris*), which are flooded in the fall for waterfowl management purposes. Further description of this area is provided by Thomson (1971).

Roost locations and counts.—Wood Duck roosts were located by following flocks of birds in flight during the evening, as described by Hein and Haugen (1966). Once a roost was found, the number of birds using it was periodically counted to determine fluctuations in usage rate.

Incoming birds were counted from a place where they could be seen crossing open fields or water adjacent to the roost. At times, accurate counts could only be made from a boat. Counts were always made by 2 experienced observers to minimize overlooking ducks on large roosts. Counts at each roost were made once or twice a week from 20 August to 30 November 1973.

Counting always started at least 1 hour before sunset, in an attempt to determine when the first bird came to roost. The last bird was assumed to have arrived after a 10-min period passed during which no more birds were seen. A Weston Master V Universal exposure meter was used to measure light intensity when the first and last birds came to roost, so that possible poor sighting conditions could be quantified.

Trapping and marking.—Wood Ducks were captured between 11 and 26 September 1973, at a permanent site waterfowl trap baited with corn, as described by Arthur and Kennedy (1972). The trap was located midway between two Wood Duck roosting sites at Union County Refuge. All 961 trapped Wood Ducks were banded with U.S. Fish and Wildlife Service leg bands so that information on movements from hunter returns might be obtained. All banded Wood Ducks were sexed and aged by plumage (Carney 1964), eye color (Kortwright 1942:221), or cloacal examination (Hochbaum 1942).

Ten banded Wood Ducks were fitted with radiotransmitter packages, so that detailed analyses of their movements could be made. Radio packages weighed approximately 20 g. Transmitters operated in the 148–149 MHz frequency range and were a modification of the type described by Cochran (1967). The radio package, mounted on the back of the duck, was attached by a harness as described by Sanderson and Schultz (1973).

Instrumented birds were located by using a battery-powered 12-channel portable tracking receiver. It was equipped with a 3-element directional hand-held yagi antenna; an 8-element yagi antenna was mounted on a vehicle for mobile reception. Once, after 4 instrumented birds left the Union County Refuge, a light aircraft (Cessna 206), with the 3-element yagi antenna mounted on 1 of the landing gear struts, was used to locate the birds.

The location of instrumented Wood Ducks was determined by direct observation, or by triangulation, as described by Heezen and Tester (1967). The birds were located approximately 4 times per week in the evening after they went to roost. They also were radio-located at 2-h intervals during several diel (24-h) tracking periods to further determine roosting habits.

To insure that movements of Wood Ducks were not affected by radio packages, they were allowed to carry them for a short acclimation period before data were gathered. The birds were fitted with radio packages on 24 and 26 September 1973, and were then released at the trap site between the roosts on Union County Refuge. The trap was approximately 2.5 km from each roost. When released, the ducks remained on the lake from 1 to 14 days, with most moving to a roost within 4 to 5 days. Once a bird flew to a roost, its movements were no longer assumed to be influenced by the radio package.

RESULTS

Factors influencing roost counts.—Four roosts were located (Fig. 1). Two roosts—"Triangle" and "Grassy Lake"—were found on the Union County

Refuge, and the other 2, called "northern" and "southern," were located at the LaRue-Pine Hills Ecological Area.

Twenty-five evening roosting flight counts were made at the Triangle Roost from 20 August to 30 November 1973. The peak count of 2100 Wood Ducks was made on 21 September 1973. On the last count, 30 November, numbers had dwindled to nearly zero. At the Grassy Lake Roost, 7 counts were made from 2 September to 14 October 1973, after which it became impossible to make any more accurate counts due to the large number of other species of waterfowl flying to the roost. The peak count of 1500 Wood Ducks was made at this roost on 23 September 1973. Figures 2 and 3 show the trends and variability in these roosting flight counts. The late September peak and subsequent decline coincide with the results reported by Hein and Haugen (1966), but the counts showed highly irregular fluctuations similar to Hartowicz's (1965) results in southeast Missouri. For example, the decline in the Triangle Roost count on 20 September could not be explained by any environmental change. Triangle Roost counts did not show a significant correlation with changes in temperature ($r = .37$, $p > 0.05$), but were slightly positively correlated with decreasing day length ($r = .50$, $p < 0.05$), using the Pearson correlation coefficient (Snedecor and Cochran 1967:172). Using the SPSS multiple-regression computer program (Nie et al. 1970) no significant relationship ($p > 0.01$) was revealed between the numbers of birds counted and any combination of the daily parameters of temperature, day length, light intensity when the first bird arrived at the roost, or % of the birds arriving before sunset (the number of counts on the Grassy Lake Roost was too small to be analyzed this way). Hein (1961 and 1965) also found no single climatic factor correlated with changes in numbers in roosting flights. Likewise, Tabberer et al. (1971) found that temperature, wind velocity, barometric pressure, and relative humidity had no effect on the number of ducks observed during roosting flight counts.

One cause of the fluctuations in counts at the Grassy Lake Roost was that many birds were missed on some evenings because the area was too large (200 ha) for 2 observers to see all incoming ducks. However, 2 definite concentrations of birds could not consistently be found on the lake, so the area was classified as 1 roost only.

Another factor influencing these roost counts was baiting at the trap site, even though the trap was 2.5 km from both roosts. As shown in Fig. 2, counts at the roosts dropped dramatically in late September, which coincided closely with a halt in baiting on 26 September. Also, prior to and after baiting, very few Wood Ducks entered either roost from the direction of the trap, but during the period of baiting, most of the flight to both roosts was from that direction. When the Illinois hunting season opened (after trapping

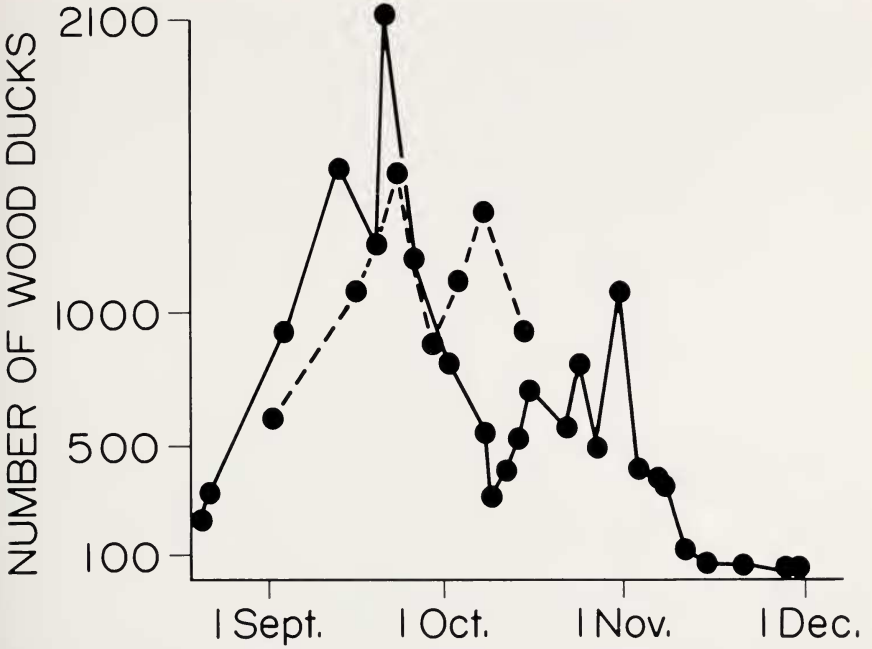

FIG. 2. Numbers of Wood Ducks counted at the Triangle Roost (solid line) and the Grassy Lake Roost (dashed line) during evening roosting flights from 20 August to 30 November 1973.

stopped), 19 ducks banded at the Union County Refuge (which included 2 instrumented birds) were recovered in the Oakwood Bottoms Greentree Reservoir feeding area (24 km north) and the LaRue-Pine Hills Ecological Area (14 km north). Since the 2 instrumented ducks (G and I) that originally fed and roosted at the Union County Refuge were known from tracking to have shifted their roost to the LaRue-Pine Hills Ecological Area and their feeding grounds to Oakwood Bottoms, it is likely that many of the other 17 refuge-banded birds that were recovered at Oakwood Bottoms and Pine Hills also were roosting at the LaRue-Pine Hills Ecological Area. These data indicate, then, that many birds that were feeding, and probably roosting, at the Union County Refuge moved to a new feeding area and roost when trapping stopped. Either this occurred, or these birds originally fed at the Union County Refuge trap site, and then flew past local roosts to reach the more distant Pine Hills roosts, which was not probable.

The use of Wood Duck roosts by large numbers of other waterfowl also caused counting problems in that rapidly flying birds could not always be differentiated as to species. The roosts on Union County Refuge were used

by Mallards (*Anas platyrhynchos*), Black Ducks (*Anas rubripes*), Green-winged Teal (*Anas crecca*), Blue-winged Teal (*Anas discors*), American Wigeon (*Anas americana*) and Canada Geese (*Branta canadensis*), as each migrated into the area. All of these species used the Triangle Roost during the day, but only Blue-winged and Green-winged teal came to this roost in significant numbers during the evening roosting flight. At the Grassy Lake Roost, however, Wood Duck counts were badly hampered by large numbers of Mallards, Black Ducks, American Wigeon, Green-winged Teal, and Canada Geese flocking to the area in the evening. The last attempt to make a count at the Grassy Lake Roost was on 18 October, when it proved impossible due to the large number of species using the roost.

Lighting conditions sometimes appeared to interfere with counting ducks, so light intensity readings were taken when the first and last birds in the evening roosting flight arrived. During these episodes, Wood Ducks were much more difficult to see in the dull light of cloudy days, particularly if they were not observed against a sky background. The increasing difficulty, though, was mainly due to the difference in the quality of the light and not the level of light intensity, since this remained at about 5 footcandles for the latest birds whether it was a clear or cloudy day.

Initial radiotracking indicated that some Wood Ducks were flying to the roost throughout the day. Consequently, Wood Duck activity was monitored at 2-h intervals during diel tracking periods to determine when birds were moving to and from roosting areas. The activity data indicated that Wood Ducks did not always return at the usual time of the evening roosting flight. Instrumented birds were observed flying to the roost both before the count was initiated and after it was completed. Ducks B, C, and E at least once each returned 3 to 6 h before counting began. Duck A once flew to the roost from its diurnal habitat during the night.

The direction from which a Wood Duck approached a roost in the evening also affected whether or not it could be counted. This was particularly apparent at the large Grassy Lake Roost where it was possible for a Wood Duck to fly unobserved to the roost if it did not return by commonly used flight lanes. An example of this is shown in Fig. 3, where an instrumented bird flew to the roost from the southeast through trees, rather than across open water as most roosting birds did and, therefore, would have been missed in the count.

Monitoring of the daily activity of Wood Ducks also revealed that some birds did not fly back to a communal roost every evening. One reason for this was that some birds continued to use the same swamp during the daytime. Instrumented Wood Ducks failed to leave the site during the day a total of 25 out of 46 diel tracking periods, or 54% of the time. An observer moving

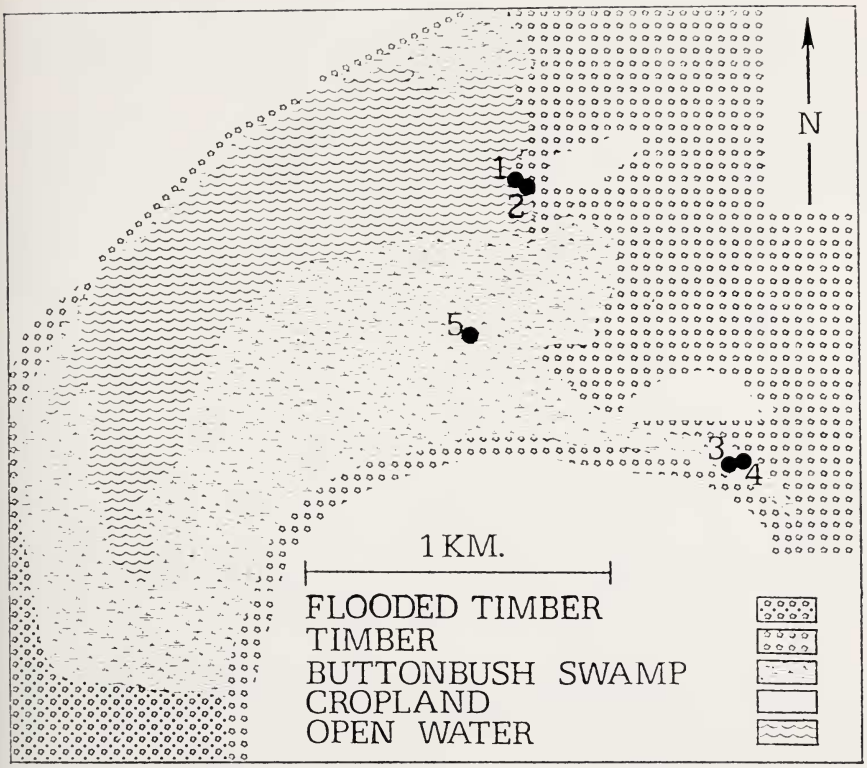

FIG. 3. Diel movements of Duck B on 11–12 November 1973. Times (CST) of locations were: (1) 17:50 11 November; (2) 05:30 12 November; (3) 07:30, 09:30 and 11:30 12 November; (4) 13:30 and 15:30 12 November; and (5) 17:30 12 November. Sunrise was at 06:42. Sunset was at 16:47. Stationary nighttime locations not included.

through a roosting swamp could flush Wood Ducks all day long. This continuous use also has been reported by Hankla and Smith (1963), who noted that, at least in the South, roosts appeared to be used for daytime feeding.

Other Wood Ducks failed to return to their roosts once they left in the morning. This did not occur until the last 3 weeks of November, which was just prior to the roosts being abandoned as the birds moved south. At this time, some Wood Ducks were observed going to roost in other areas close to, but not in, the Triangle Roost, and instrumented birds occasionally failed to return from their diurnal habitat to the roost. On 3 occasions Duck A, and once Duck F, failed to return to the roost from the area in which they were feeding during the day. In another instance, Duck A returned to the roost vicinity just after sunset from an unknown location. Instead of going to the usual roost site, however, the bird roosted in nearby flooded timber.

Table 1

Percent of the Days Individual Wood Ducks were Exposed to a Roosting Flight Count*

Wood Duck I.D. code	No. days calculated	No. days exposed	% time exposed to counting
A	15	4	27
B	16	8	50
C	13	9	69
D	20	12	60
E	10	7	70
F	21	2	10
G	2	2	100
H	7	1	14
I	2	2	100
J	10	0	0
Total	116	47	
Mean	11.6	4.7	50
Weighted mean			41

* The number of days used in the calculation was the number of days individual birds could be located before and after a roosting flight count would have been made.

A final factor that could have caused unreliable roost counts was the movement of Wood Ducks from one roost to another. The frequency with which Wood Ducks used the same roost was determined by locating instrumented birds after the evening roosting flight. Individual birds were located on the same roost 97% of the time ($N = 295$ observations), with ducks G and I the only birds displaying inter-roost movement. Duck G moved from the Triangle Roost to the Grassy Lake Roost and then to the northern roost at LaRue-Pine Hills Ecological Area. Duck I moved from the Grassy Lake Roost to the northern roost at LaRue-Pine Hills Ecological Area.

To determine the overall frequency and consistency with which the individual instrumented birds exposed themselves to a count at their usual roost, they were located prior to the evening roosting flight and then again during the flight or immediately following it. The results, summarized in Table 1, show that the weighted mean for all birds exposed to a count was 41% ($\pm 31\%$, $p < 0.05$—confidence limits from the method of Snedecor and Cochran 1967:210). Counting exposure data were further analyzed to determine if instrumented birds as a group showed any environmentally-related trend in exposing themselves to a count. For each of the 17 days in which at least 4 birds were located before and after the roosting flight, the percent exposed to a count on that day was calculated. As indicated in Fig. 4, there was no apparent trend with season. Multiple linear regression analyses

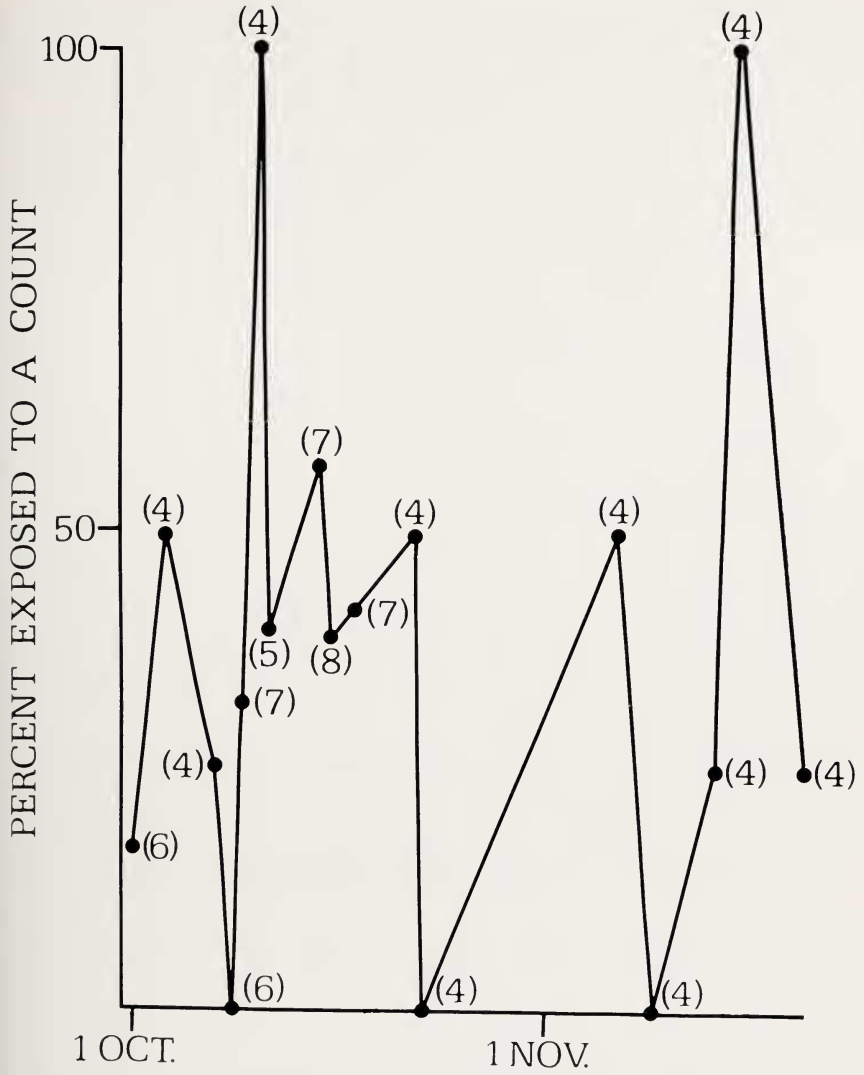

FIG. 4. Percentage of instrumented Wood Ducks exposed to evening roosting flight counts on individual days. Only those days when 4 or more birds could be located before and after the roosting flight were used. Numerals in parentheses equal the number of birds located that day.

revealed no relationship ($p > 0.01$) between the % exposed to a count and daily maximum, minimum, and mean temperature, day length, or number of birds being counted. The weighted mean % of all birds exposed for any given day was 37% ($\pm$ 24%, $p < 0.05$). Not leaving the roost during the day

TABLE 2

SUMMARY OF INSTRUMENTED BIRDS' FAILURE TO MEET ASSUMPTIONS NECESSARY FOR ROOST COUNTS TO PROVIDE AN ACCURATE CENSUS OF WOOD DUCKS*

Assumption:	Number of times failed (69/116)	Percent of total failures (69)	Percent of total (116)
1. Roosts are geographically discrete.	3	4.3	2.6
2. Roost count is not affected by surrounding food or water.	Unknown number	–	–
3. All birds flying to a roost are susceptible to counts at a normal time.			
A. No confusion due to other waterfowl.	Unknown number	–	–
B. Lighting conditions are suitable.	Unknown number	–	–
C. Birds fly to roost during counting interval.	5	7.2	4.3
D. Birds approach roost from a visible direction.	3	4.3	2.6
SUBTOTAL	8	11.5	6.9
4. All birds fly to a communal roost on a given day.			
A. All birds leave roost during the day.	54	78.3	46.6
B. All birds return to roost at night.	4	5.8	3.4
SUBTOTAL	58	84.1	50.0
5. No inter-roost movement.	0	0	0
TOTAL	69	99.9	59.5

* Observations were made on 116 roosting flights by individual instrumented birds.

was the most common reason for Wood Ducks not being exposed to a count. Table 2 summarizes the relative importance of the other reasons why Wood Ducks would have been missed in roosting flight counts.

The number of counts necessary to obtain an accurate estimate of the size of a roosting population was calculated based upon the day-to-day variation in movements of the 10 individual instrumented birds as well as the group as a whole. The number of counts necessary was determined using the technique given by Snedecor and Cochran (1967:58). Using the sample variance of the mean (Snedecor and Cochran 1967:44) of individual birds being exposed to a count (weighted mean equals 41%) as an estimator of the population variance, 22 roost counts would be necessary for 15% accuracy at the 95% confidence level. Using the variance in the total percentage of instrumented birds exposed on a single day (weighted mean equals 37%),

15 counts would be necessary for accuracy within 15% at the 95% confidence level.

DISCUSSION

The changes in Wood Duck roosting flight counts in this study (Figs. 2 and 3) corresponded with those reported by Hein and Haugen (1966). Hein (1961) felt the September peak in numbers was due to this being the time when most adults and juveniles were capable of flight. The decline in the roosting flight count after the September peak was thought to be due to dispersal of birds in all directions (Stewart 1958). The movement of 19 banded and instrumented birds 14 km north of the banding site in this study tended to verify the dispersal concept. This is further supported by Brown (1972) who found, through band and tag returns, that there was a late summer dispersal of adult and juvenile male Wood Ducks as far north as Wisconsin from Arkansas. The smaller October peaks in counts in this study probably were due to new migrants moving into the area, as Hein and Haugen (1966) concluded in Iowa.

Although the counts of roosting Wood Ducks in southern Illinois followed the general trends found in other studies, all of our 5 previously described requisites for a roost count to be a valid indexing technique were not met throughout the autumn. Results of this study, in relation to the 5 assumptions, were:

1. All roosts were not geographically discrete, as revealed by the problems in identifying the roosts at the large Grassy Lake Roost area. Hein and Haugen (1966:660) noted that a large Iowa roost had "three foci within slightly less than 1 square mile," and that "at some marshes, Wood Ducks used several roosting sites." This indicates that large, indistinct roosts are not unique to southern Illinois.

2. The presence of a food supply apparently can affect the number of birds flying to local roosts, as was shown by the change in the direction of roosting flights when bait was present at a trap site and by the movement of birds from the trap to the Oakwood Bottoms Greentree Reservoir where acorns were becoming available as a new source of food. The numbers of Wood Ducks flying to roosts also are evidently affected by the existing water conditions. Roosts were abandoned when they went dry (Smith 1958, Hein and Haugen 1966), and Tabberer et al. (1971) found that as surface water increased, the numbers of ducks observed during roosting flights decreased.

3. There were 4 reasons why Wood Ducks that flew to a roost were sometimes not susceptible to being counted. One reason was that the common use of roosts by several other species of waterfowl caused problems in

identifying and counting Wood Ducks. This was in contrast to a report by Hein and Haugen (1966), who stated that the Blue-Winged Teal was the only species found using Wood Duck roosts, and that this was infrequent in Iowa. Second, poor lighting conditions due to cloudy weather interfered with counting ducks. A third factor that limited susceptibility of flying Wood Ducks to being counted was that some birds flew to the roost either before or after the time in the evening when a roost count would normally be made. The only way this problem could be avoided would be for an observer to stay at the roost all day. Also, some of the birds flying to the roost early did not remain there, so the observer would have to continuously count birds leaving, as well as entering, the roost. The fourth factor causing some birds flying to the roost to be missed in a count was that birds occasionally approached the roost from a direction that prevented them from being seen. This could be a serious problem in an area where the direction of flight to available local food supplies might be changed from day to day.

4. Our fourth major assumption, that all of the Wood Ducks in an area fly to a roost in the evening, also was proved false. Some birds did not leave the roost on some days, and others failed to return some evenings. The failure of birds to leave the roost was the major cause for this assumption to be violated more than any of the other 4. Birds failed to return to the roost in the evening only late in the study (November) and, if roosting counts were made between 15 and 30 September, this part of the problem would have been avoided.

5. The last requisite, an absence of unilateral inter-roost movement, was essentially met. Instrumented birds were located on their primary roost 97% of the time.

The overall effect of the failure of most of these assumptions to be met on a consistent basis was that individual instrumented birds exposed themselves to a count on an average of only 41 ($\pm$ 31) % of the days they were observed, while the average number of all instrumented birds exposed to a count on any given day was 37 ($\pm$ 24) %.

Hein and Haugen (1966), from their study of roosts on the upper Mississippi River in Iowa, concluded that 50% or greater of the roosts in an area must be counted to detect changes of 15% in annual abundance of Wood Ducks. They also stated that, with a sample size of 25 roosts, and assuming a 95% confidence level, the maximum precision in average roosting flight counts per roost was about 3% in 2 successive falls. However, data from this study indicated that, due to the variation in counting exposure among individual birds and different days, 15 to 22 roosting flight counts must be made for accuracy within 15% at the 95% confidence level. Therefore, assuming this variance would be as great for a large number of birds, such

as seen in a roost count, and that all roosts were counted on the same day, the smallest area to which the index could be applied would be the area enclosing 15 to 22 roosts. This area could be reduced by counting some roosts more than once on different days, but this would cause an extension of the time required, which would be undesirable due to the constant change in roosting numbers with time as shown in Figs. 2 and 3. Realistically, chances of most researchers being able to economically synchronize 15 to 22 counts within a 2- or 3-day period appear to be small.

The high amount of individual and daily variability seen in the counting susceptibility of instrumented birds provided a quantitative basis for suspecting the accuracy of day-to-day roost counts. Additional observed variables that were not quantified, such as seasonal food and water availability, counting confusion due to the presence of other waterfowl, and poor sighting conditions, could cause daily and seasonal counting errors to be even higher.

A final unknown variable which might affect local counts of Wood Ducks is unusually early cold weather forcing additional migrants into an area, causing a local inflation of counts in southern areas and a decrease at northern roosts. What makes this factor particularly troublesome is that a change at one roost would probably have a corresponding opposite effect on other roosting areas, since ducks are highly mobile. The result is that an index in one location may be representing conditions over a larger, completely unknown geographic area. Counting errors such as this would be unknown to the biologist unless roost counts were made simultaneously throughout the flyway; this is not yet practicable.

SUMMARY

Wood Ducks were equipped with radio packages, and their roosting flights were observed throughout the fall to determine the validity of using flight counts as a Wood Duck population index. Seasonal trends in the numbers of ducks flying to roosts were similar to the results of other workers, but the trends could not be related to environmental factors such as temperature, day length, or light intensity. Evening roosting flight counts did not provide a valid index to Wood Duck population size for several reasons: (a) roosts were not always geographically discrete; (b) a changing food supply location caused the number of Wood Ducks flying to a roost to vary; (c) all birds that flew to a roost were not susceptible to being counted, because of confusion due to the presence of other waterfowl, poor lighting resulting from cloudy weather, birds not flying to the roost during the counting interval, or birds approaching the roost from a direction which offered poor counting visibility; (d) some birds did not fly to a communal roost on certain days, either because they never left the roost, or because they roosted alone elsewhere. Most ducks did, however, show high fidelity to their traditional roosts. The variability in the exposure of instrumented Wood Ducks to counting could not be related to temperature, day length, or the total number of birds being counted. As a result of this variability, 15 to 22 roost counts would have to be conducted simultaneously in an area for 15%

accuracy at the 95% confidence level. We do not feel that this counting intensity is practical.

ACKNOWLEDGMENTS

We are indebted to David Kennedy, Staff Waterfowl Biologist, Illinois Department of Conservation, for his assistance in conducting this study. We are grateful to Karen Crites, Robert Hileman, Fred Roetker, and Vic Hammer for their help in the field. We would like to thank Mike Sweet for supplying information on banded Wood Ducks killed in Oakwood Bottoms Greentree Reservoir, and we thank W. D. Klimstra, Cooperative Wildlife Research Laboratory, Southern Illinois University, for providing radiotelemetry receiving equipment. We thank Joe Newcomb, District Ranger, U. S. Forest Service for allowing access to U. S. Forest Service lands. The Max McGraw Wildlife Foundation and the Illinois Department of Conservation financed part of this study. We appreciate the financial support of Amax Coal Company in paying publication costs for this article.

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